San Joaquin County Public Workshop: Presentation of Findings for San Joaquin County Groundwater Basin Studies

Hosted by San Joaquin County Public Works Department

Presented by U.S. Geological Survey California Water Science Center

San Joaquin County Public Workshop: Presentation of Findings for San Joaquin County Groundwater Basin Studies

March 26, 2014, 1:00pm – 5:00pm
San Joaquin County - Robert J. Cabral Agricultural Center
2101 E. Earhart Ave., Assembly Room 3
Stockton, CA

Agenda

1. Introduction: Gerardo Dominguez, SJC Public Works
2. Introduction of speakers: John Izbicki, USGS, CA Water Science Center
3. USGS Presentations
   - **John Izbicki:** Overview of USGS Study Results in Northeastern San Joaquin Groundwater Subbasin: Implications for Water Quality and Groundwater Recharge
   - **David O'Leary:** Movement of Recharge Water from Land Surface to Wells
   - **Loren Metzger:** Chloride Mapping on the Basis of Electromagnetic Log Data

Questions (10 minutes)

Break (15 minutes)

- **George Bennett:** Status and Understanding of Groundwater Quality in the Northern San Joaquin Basin, 2005: California GAMA Priority Basin Project
- **Claudia Faunt:** Central Valley Hydrologic Flow Model
- **Steve Phillips:** Development of Hydrologic Model for Evaluating Water Management Strategies in the Stanislaus -Tuolumne River Groundwater Basin

Questions (10 minutes)

Break (15 minutes)

- **Michelle Sneed:** Land Subsidence along the Delta-Mendota Canal in the Northern San Joaquin Valley, California, 2003–10
- **Jonathan Traum:** Groundwater Flow Model for Evaluation of Hydraulic Effects of the San Joaquin River Restoration

Questions (10 minutes)

4. Closing remarks: John Izbicki, Gerardo Dominguez

Abstracts

Note: Below each abstract is a list of publications corresponding or related to the abstract with a digital link to the publication, if available. Abstracts are listed in the same order as presented.

Overview of USGS study results in the Northeastern San Joaquin Groundwater Subbasin: Implications for water quality and groundwater recharge

By John A. Izbicki

Modified from:

*Groundwater Data for Selected Wells within the Eastern San Joaquin Groundwater Subbasin, California, 2003–8**

Abstract

Data were collected by the U.S. Geological Survey from 2003 through 2008 in the Eastern San Joaquin Groundwater Subbasin, 80 miles east of San Francisco, California, as part of a study of the increasing chloride concentrations in groundwater processes. Data collected include geologic, geophysical, chemical, and hydrologic data collected during and after the installation of five multiple-well monitoring sites, from three existing multiple-well sites, and from 79 selected public-supply, irrigation, and domestic wells. Each multiple-well monitoring site installed as part of this study contained three to five 2-inch diameter polyvinyl chloride (PVC)-cased wells ranging in depth from 68 to 880 feet below land surface. Continuous water-level data were collected from the 19 wells installed at these 5 sites and from 10 existing monitoring wells at 3 additional multiple-well sites in the study area. Thirty-one electromagnetic logs were collected seasonally from the deepest PVC-cased monitoring well at seven multiple-well sites. About 200 water samples were collected from 79 wells in the study area. Coupled well-bore flow data and depth-dependent water-quality data were collected from 12 production wells under pumped conditions, and well-bore flow data were collected from 10 additional wells under unpumped conditions.

*Clark, D.A., Izbicki, J.A., Metzger, L.F., Everett, R.R., Smith, G.A., O'Leary, David, Teague, N.F., and Burgess, M.K., 2012, Groundwater Data for Selected Wells within the Eastern San Joaquin Groundwater Subbasin, California, 2003–8: U.S. Geological Survey Data Series 696, 154 p. http://pubs.usgs.gov/ds/696/.

Movement of Recharge Water from Land Surface to Wells*

By David O'Leary

Abstract

Local surface water and stormflow were infiltrated intermittently from a 40-ha basin between September 2003 and September 2007 to determine the feasibility of recharging alluvial aquifers pumped for public supply, near Stockton, California. Infiltration of water produced a pressure response that propagated through unconsolidated alluvial-fan deposits to 125 m below land surface (bls) in 5 d and through deeper, more consolidated alluvial deposits to 194 m bls in 25 d, resulting in increased water levels in nearby monitoring wells. The top of the saturated zone near the basin fluctuates seasonally from depths of about 15 to 20 m. Since the start of recharge, water infiltrated from the basin has reached depths as great as 165 m bls. On the basis of sulfur hexafluoride tracer test data, basin water moved downward through the saturated alluvial deposits until reaching more permeable zones about 110 m bls. Once reaching these permeable zones, water moved rapidly to nearby pumping wells at rates as high as 13 m/d. Flow to wells through highly permeable material was confirmed on the basis of flowmeter logging, and simulated numerically using a two-dimensional radial groundwater flow model. Arsenic concentrations increased slightly as a result of recharge from 2 to 6 μg/L immediately below the basin. Although few water-quality issues were identified during sample collection, high groundwater velocities and short travel times to nearby wells may have implications for groundwater management at this and at other sites in heterogeneous alluvial aquifers.

*O'Leary, D. R., J.A. Izbicki, J.E. Moran, T. Meeth, B. Nakagawa, L. Metzger, C. Bonds, and M.J. Singleton, 2012, Movement of Water Infiltrated from a Recharge Basin to Wells: Groundwater, vol. 50, no. 2, p 242-255. http://pubs.er.usgs.gov/publication/70039979.

Chloride Mapping on the Basis of Electromagnetic Log Data

By Loren Metzger

Modified from:

*Electromagnetic-Induction Logging to Monitor Changing Chloride Concentrations**

Abstract

Water from the San Joaquin Delta, having chloride concentrations up to 3,590 mg/L, has intruded freshwater aquifers underlying Stockton, Calif. Changes in chloride concentrations at depth within these aquifers were evaluated using sequential electromagnetic (EM) induction logs collected during 2004-07 at seven multiple-well sites as deep as 268 m. Sequential EM logging is useful for identifying changes in groundwater quality through PVC-cased wells in intervals not screened by wells. These unscreened intervals represent more than 90% of the aquifer at the sites studied. Sequential EM logging suggested degrading groundwater quality in numerous thin intervals, typically between 1 and 7 m thick, especially in the northern part of the study area. Some of these intervals were unscreened by wells, and would not have been identified by traditional groundwater sample collection. Sequential logging also identified intervals with improving water quality—possibly due to groundwater management practices that have limited pumping and promoted artificial recharge. EM resistivity was correlated with chloride concentrations in sampled wells and in water from core material. Natural gamma log data were used to account for the effect of aquifer lithology on EM resistivity. Results of this study show sequential EM logging is useful for identifying and monitoring movement of high-chloride water, having lower salinities and chloride concentrations than seawater, in aquifer intervals not screened by wells, and that increases in chloride in water from wells in the area are consistent with high-chloride water originating from the San Joaquin Delta rather than from the underlying saline aquifer.

* Metzger, L.F. and Izbicki, J.A. (2013), Electromagnetic-Induction Logging to Monitor Changing Chloride Concentrations. Ground Water, 51: 108-121. Doi: 10.1111/j.1745-6584.2012.00944.x
http://pubs.er.usgs.gov/publication/70095242.

Status and Understanding of Groundwater Quality in the Northern San Joaquin Basin, 2005: California GAMA Priority Basin Project*

By George Bennett

Abstract

Groundwater quality in the 2,079 square mile Northern San Joaquin Basin (Northern San Joaquin) study unit was investigated from December 2004 through February 2005 as part of the Priority Basin Project of the Groundwater Ambient Monitoring and Assessment (GAMA) Program. The GAMA Priority Basin Project was developed in response to the Groundwater Quality Monitoring Act of 2001 that was passed by the State of California and is being conducted by the California State Water Resources Control Board in collaboration with the U.S. Geological Survey and the Lawrence Livermore National Laboratory.

The Northern San Joaquin study unit was the third study unit to be designed and sampled as part of the Priority Basin Project. Results of the study provide a spatially unbiased assessment of the quality of raw (untreated) groundwater, as well as a statistically consistent basis for comparing water quality throughout California. Samples were collected from 61 wells in parts of Alameda, Amador, Calaveras, Contra Costa, San Joaquin, and Stanislaus Counties; 51 of the wells were selected using a spatially distributed, randomized grid-based approach to provide statistical representation of the study area (grid wells), and 10 of the wells were sampled to increase spatial density and provide additional information for the evaluation of water chemistry in the study unit (understanding/flowpath wells).

The primary aquifer systems (hereinafter, primary aquifers) assessed in this study are defined by the depth intervals of the wells in the California Department of Public Health database for each study unit. The quality of groundwater in shallow or deep water-bearing zones may differ from quality of groundwater in the primary aquifers; shallow groundwater may be more vulnerable to contamination from the surface. Two types of assessments were made: (1) *status*, assessment of the current quality of the groundwater resource; and (2) *understanding*, identification of the natural and human factors affecting groundwater quality.

Relative-concentrations (sample concentrations divided by benchmark concentrations) were used for evaluating groundwater quality for those constituents that have Federal or California regulatory or non-regulatory benchmarks for drinking-water quality. Benchmarks used in this study were either health-based (regulatory and non-regulatory) or aesthetic based (non-regulatory). For inorganic constituents, relative-concentrations were classified as high (equal to or greater than 1.0), indicating relative-concentrations greater than benchmarks; moderate (equal to or greater than 0.5, and less than 1.0); or, low (less than 0.5). For organic and special-interest constituents [1,2,3-trichloropropane (1,2,3-TCP), *N*-nitrosodimethylamine (NDMA), and perchlorate], relative-concentrations were classified as high (equal to or greater than 1.0); moderate (equal to or greater than 0.1 and less than 1.0); or, low (less than 0.1).

Aquifer-scale proportion was used as the primary metric in the *status assessment* for groundwater quality. High aquifer-scale proportion is defined as the percentage of the primary aquifer with relative-

concentrations greater than 1.0; moderate and low aquifer-scale proportions are defined as the percentage of the primary aquifer with moderate and low relative-concentrations, respectively. The methods used to calculate aquifer-scale proportions are based on an equal-area grid; thus, the proportions are areal rather than volumetric. Two statistical approaches—grid-based, which used one value per grid cell, and spatially weighted, which used the full dataset—were used to calculate aquifer-scale proportions for individual constituents and classes of constituents. The spatially weighted estimates of high aquifer-scale proportions were within the 90-percent confidence intervals of the grid-based estimates in all cases. The *understanding assessment* used statistical correlations between constituent relative-concentrations and values of selected explanatory factors to identify those factors potentially affecting constituent relative-concentrations and occurrence. Individual constituents detected at high relative-concentrations or those detected at low relative-concentrations in substantial proportions of the aquifer (greater than 10 percent) were evaluated statistically in relation to selected explanatory factors. Explanatory factors evaluated in this report were land use, well depth, depth to top-of-perforation, lateral and vertical position within the flow system, groundwater age, and geochemical conditions.

The *status assessment* for inorganic constituents showed that relative-concentrations (one or more) were high, relative to health-based benchmarks, in 13 percent of the primary aquifer, moderate in 29 percent, and low in 58 percent. High relative-concentrations of inorganic constituents in the primary aquifer reflected high proportions of arsenic (high relative-concentrations in 9.4 percent of the aquifer) and boron (7.6 percent). Inorganic constituents with aesthetic-based benchmarks [non-regulatory secondary maximum contaminant levels (SMCLs)], manganese, iron, total dissolved solids (TDS), chloride, and sulfate, were detected at high relative-concentrations in 34, 11, 5.8, 3.9, and 2 percent of the primary aquifer, respectively. SMCLs are benchmarks given to constituents with technical properties that can make drinking water undesirable with respect to taste, staining, or scaling at high relative-concentrations.

The *status assessment* for organic constituents showed that relative-concentrations (one or more) were high in 2.7 percent, moderate in 6.9 percent, and low in 90 percent of the primary aquifer of the Northern San Joaquin study unit. High relative-concentrations of organic constituents in the primary aquifer reflected high relative-concentrations of the discontinued soil fumigant 1,2-dibromo-3-chloropropane (DBCP, 2.7 percent of the primary aquifer). Maximum relative-concentrations were equal to or greater than 0.1 and (or) a detection frequency greater than 10 percent for five organic constituents: chloroform, DBCP, methyl *tert*-butyl ether (MTBE), simazine, and tetrachloroethylene (PCE).

The *understanding assessment* for inorganic constituents showed that groundwater age, normalized lateral position, and redox conditions were the most significant explanatory factors related to inorganic constituent relative-concentrations. Groundwater age was shown to be associated with relative-concentrations of arsenic, gross alpha radioactivity, and total dissolved solid (TDS). High and moderate relative-concentrations of arsenic, iron, and manganese primarily were associated with geochemical conditions. Relative-concentrations of arsenic were high in oxygen-rich high-pH waters and in anoxic waters. High relative-concentrations of iron and manganese were most often associated with low-oxygen anoxic waters. Normalized lateral position, a sampled well’s position in the Northern San Joaquin study unit relative to the basin center and basin edge, was shown to be associated with arsenic, nitrate, and TDS relative-concentrations. High and moderate relative-concentrations of arsenic and TDS were found more frequently closer to the valley trough (basin center), where relative-concentrations of nitrate tended to decrease, than in wells near the valley margins (basin edges). The *understanding assessment* for organic constituents showed that groundwater age, well depth, and land use within 500 meters of the sampled well were the most significant factors affecting organic constituent relative-concentrations. Trihalomethanes, fumigants, pesticides, and solvents were all shown to have higher relative-concentrations in young groundwater than in old groundwater. Fumigant and pesticide relative-concentrations were related to well perforation depth, with wells with shallow depths to top-of-perforation having higher constituent relative-concentrations than those with deeper depths to top-of-perforation. Detections of trihalomethanes and solvents were positively associated with urban land use and negatively associated with agricultural land use. Fumigant detections were strongly correlated with a specific agricultural land use—orchards and vineyards.

Belitz, K., and Landon, M.K., 2010, Groundwater Quality in the Central Eastside San Joaquin Valley, California: U.S. Geological Survey Fact Sheet 2010-3001, 4 p. http://pubs.usgs.gov/fs/2010/3001/.

*Bennett, G.L., V, Fram, M.S., Belitz, Kenneth, and Jurgens, B.C., 2010, Status and understanding of groundwater quality in the Northern San Joaquin Basin, 2005: California GAMA Priority Basin Project: U.S. Geological Survey Scientific Investigations Report 2010–5175, 82 p. http://pubs.usgs.gov/sir/2010/5175/.

Bennett, G.L., V, and Belitz, K., 2010, Groundwater quality in the Northern San Joaquin Valley, California: U.S. Geological Survey Fact Sheet 2010-3079, 4 p. http://pubs.usgs.gov/fs/2010/3079/.

Bennett, G.L., V, Belitz, Kenneth, Milby Dawson, B.J., 2006, California GAMA Program—Ground-water quality data in the Northern San Joaquin basin study unit, 2005: U.S. Geological Survey Data Series 196, 122 p. http://pubs.usgs.gov/ds/2006/196/ds_196.pdf.

Landon, M.K., Belitz, Kenneth, Jurgens, B.C., Kulongoski, J.T., and Johnson, T.D., 2010, Status and understanding of groundwater quality in the Central–Eastside San Joaquin Basin, 2006: California GAMA Priority Basin project: U.S. Geological Survey Scientific Investigations Report 2009–5266, 97 p. http://pubs.usgs.gov/sir/2009/5266/.

Updates to the US Geological Survey's Central Valley Hydrologic Model

By Claudia Faunt

Abstract

California's Central Valley has been one of the most productive agricultural regions in the world; however, groundwater pumping for irrigation has caused groundwater-level declines and associated land subsidence. Recent drought conditions caused increased demand for groundwater, resulting in land subsidence. The potential damages in surface infrastructure from subsidence may cause managers to limit groundwater withdrawals both spatially and temporally. The U.S. Geological Survey (USGS) recently developed the Central Valley hydrologic model (CVHM) to quantitatively assess aquifer-system responses to climatic variation, surface-water deliveries, and groundwater pumping. To more accurately simulate the recent groundwater levels and the spatial distribution, timing, and magnitudes of subsidence, the CVHM has been updated. MODFLOW-FMP has been enhanced to more accurately simulate the timing of subsidence by incorporating effects layers that delay deformation, changes in altitudes caused by subsidence (grid deforms), and separation of the inelastic and elastic portions of subsidence. More recent data were added to extend the simulation through 2009 and recalibrate CVHM to recent groundwater-level and subsidence data. The updated CVHM provides a detailed analysis of changes in groundwater availability and subsidence and can be used to assist decision makers in making water management decisions necessary to achieve effective conjunctive use.

Faunt, Claudia C., Hanson, Randall T., Belitz, Kenneth, Rogers, Laurel, 2009, California's Central Valley Groundwater Study: A Powerful New Tool to Assess Water Resources in California's Central Valley: U.S. Geological Survey Fact Sheet 2009-3057, 4p. http://pubs.er.usgs.gov/publication/fs20093057.

Faunt, Claudia C. (editor), 2009, Groundwater Availability of the Central Valley Aquifer, California: U.S. Geological Survey Professional Paper 1766, 227 p. http://pubs.er.usgs.gov/publication/pp1766.

Development of a Hydrologic Model for Evaluating Water Management Strategies in the Stanislaus-Tuolumne River Ground-Water Basin, CA

By Steven P Phillips

Modified from:

*Simulation of multiscale ground-water flow in part of the northeastern San Joaquin Valley, California**

Abstract

Strategies for managing local water supplies and groundwater quality are being formulated and evaluated by the Stanislaus-Tuolumne River Groundwater Basin Association (STRGBA). Management issues and goals in the basin include an area in the lower part of the basin that requires drainage, intra- and inter-basin migration of poor-quality groundwater, increasing groundwater use associated with new development, and efficient management of surface and groundwater supplies. To aid in the evaluation of water management strategies, the U.S. Geological Survey and the STRGBA have developed a hydrologic model that simulates monthly groundwater and surface-water flow as dictated by aquifer-system properties, climatically-driven water supply, water use, and land use. The model is calibrated to groundwater levels and streamflow measured between 1960 and 2004. Available measured groundwater pumpage values for municipal, irrigation, and drainage purposes are specified in the model, as are deliveries of surface water. Private irrigation pumpage and recharge associated with agricultural land use are estimated using the new Farm Process in MODFLOW-2005, which simulates irrigated agriculture. Hydraulic conductivity values of the aquifer system are constrained using data from more than 3,500 drillers' logs. Preliminary simulation results will be discussed.

*Phillips, S.P., Green, C.T., Burow, K.R., Shelton, J.L., and Rewis, D.L., 2007, Simulation of multiscale ground-water flow in part of the northeastern San Joaquin Valley, California: U.S. Geological Survey Scientific Investigations Report 2007-5009, 43 p. http://pubs.er.usgs.gov/publication/sir20075009.

Burow, K.R., Shelton, J.L., Hevesi, J.A., and Weissmann, G.S., 2004, Hydrogeologic characterization of the Modesto area, San Joaquin Valley California: U.S. Geological Scientific Investigations Report 2004-5232, 54 p. http://pubs.usgs.gov/sir/2004/5232/.

Land Subsidence along the Delta-Mendota Canal in the Northern Part of the San Joaquin Valley, California, 2003–10*

By Michelle Sneed

Abstract

Extensive groundwater withdrawal from the unconsolidated deposits in the San Joaquin Valley caused widespread aquifer-system compaction and resultant land subsidence from 1926 to 1970—locally exceeding 8.5 meters. The importation of surface water beginning in the early 1950s through the Delta-Mendota Canal and in the early 1970s through the California Aqueduct resulted in decreased pumping, initiation of water-level recovery, and a reduced rate of compaction in some areas of the San Joaquin Valley. However, drought conditions during 1976–77 and 1987–92, and drought conditions and regulatory reductions in surface-water deliveries during 2007–10, decreased surface-water availability, causing pumping to increase, water levels to decline, and renewed compaction. Land subsidence from this compaction has reduced freeboard and flow capacity of the Delta-Mendota Canal, the California Aqueduct, and other canals that deliver irrigation water and transport floodwater.

Land subsidence was assessed in the vicinity of the Delta-Mendota Canal as part of an effort to minimize future subsidence-related damages to the canal. The location, magnitude, and stress regime of land-surface deformation during 2003–10 were determined by using extensometer, Global Positioning System (GPS), Interferometric Synthetic Aperture Radar (InSAR), spirit leveling, and groundwater-level data. Comparison of continuous GPS, shallow extensometer, and groundwater-level data, combined with results from a one-dimensional model, indicated the vast majority of the compaction took place beneath the Corcoran Clay, the primary regional confining unit.

Although the northern portion of the Delta-Mendota Canal was relatively stable, land-surface deformation measurements indicated the southern portion of the Delta-Mendota Canal (Checks 15–21) subsided as part of a large subsidence feature centered about 15 kilometers northeast of the Delta-Mendota Canal, south of the town of El Nido. Results of InSAR analysis indicated at least 540 millimeters of subsidence near the San Joaquin River and the Eastside Bypass during 2008–10, which is part of a 3,200 square-kilometer area—including the southern part of the Delta-Mendota Canal—affected by 20 millimeters or more of subsidence during the same period. Calculations indicated that the subsidence rate doubled in 2008 in some areas. The GPS surveys done in 2008 and 2010 confirmed the high subsidence rate measured by using InSAR for the same period. Water levels in many shallow and deep wells in this area declined during 2007–10; water levels in many deep wells reached historical lows, indicating that subsidence measured during this period was largely inelastic. InSAR-

derived subsidence maps for various periods during 2003–10 showed that the area of maximum active subsidence (that is, the largest rates of subsidence) shifted from its historical (1926–70) location southwest of Mendota to south of El Nido.

*Sneed, Michelle, Brandt, Justin, and Solt, Mike, 2013, Land subsidence along the Delta-Mendota Canal in the northern part of the San Joaquin Valley, California, 2003–10: U.S. Geological Survey Scientific Investigations Report 2013–5142, 87 p., http://dx.doi.org/10.3133/sir20135142.

Brandt, J.T., Bawden, G.W., and Sneed, M., 2005, Evaluating Subsidence in the Central Valley, CA, using InSAR: EOS. Transactions of the American Geophysical Union, v. 85, no. 52, 2005 Fall Meeting Supplement, Abstract G51C-0851. http://adsabs.harvard.edu/abs/2005AGUFM.G51C0851B.

Groundwater Flow Model for Evaluation of Hydrologic Effects of the San Joaquin River Restoration*

By Jonathan A. Traum

Abstract

The USGS, in cooperation with the USBR, has developed a preliminary groundwater flow model (SJRRPGW) to help evaluate shallow groundwater issues for the San Joaquin River Restoration Program (SJRRP). The SJRRPGW was constructed using the USGS-MODFLOW2005 based Farm Process and is based on the framework of the USGS Central Valley Hydrologic Model (CVHM). In addition to groundwater flow, the SJRRPGW simulates the water supply and demand components of irrigated agriculture and simulates the surface-water flow and stream-aquifer interaction of the San Joaquin River. The aquifer sediment texture data used in the regional CVHM were refined to better represent the natural heterogeneity of aquifer-system materials at the scale of the SJRRPGW.

The SJRRPGW was calibrated for 1961 to 2003 using groundwater-level observations from 133 wells and streamflow observations from 19 gages. The simulated groundwater-level altitudes and trends (including seasonal fluctuations) and the simulated surface-water flow magnitudes and trends reasonably match measured data. The simulated San Joaquin River seepage-loss rates are generally consistent with rates estimated by previous studies. The preliminary calibrated model will be used to help understand the potential effects of restoration flows on agricultural drainage and the relative benefits of proposed SJRRP actions for reducing negative effects.

*Traum, J.A., Phillips, S.P., 2012, Groundwater Flow Model for Evaluation of Hydrologic Effects of the San Joaquin River Restoration, California Water and Environmental Modeling Forum, April 18, 2012, Folsom, CA, p. 24-25. http://www.cwemf.org/AnnualMeeting/2012Abstracts.pdf.

Traum, J.A., Phillips, S.P., Development of a Numerical Groundwater-Flow Model to Evaluate the Effects of the San Joaquin River Restoration Program on Stream-Aquifer Interaction, National Ground Water Summit, May 7, 2012, Garden Grove, CA, https://ngwa.confex.com/ngwa/2012gws/webprogramsummit/Paper8284.html

Traum, J.A., Phillips, S.P., Bennett, G.L., Metzger, L.F., Zamora, C., 2014, Numerical Hydrologic and Groundwater Flow Model for the San Joaquin River Restoration Program: U.S. Geological Survey Scientific Investigations Report 2014-XXXX, not yet published.

List of USGS Publications funded by NESJGBA

Clark, D.A., Izbicki, J.A., Metzger, L.F., Everett, R.R., Smith, G.A., O'Leary, David, Teague, N.F., and Burgess, M.K., 2012, Groundwater Data for Selected Wells within the Eastern San Joaquin Groundwater Subbasin, California, 2003–8: U.S. Geological Survey Data Series 696, 154 p. http://pubs.usgs.gov/ds/696/

Izbicki, John A., Metzger, Loren F., McPherson, Kelly R., Everett, Rhett R., Bennett, George L., V., 2006, Sources of High-Chloride Water to Wells, Eastern San Joaquin Ground-Water Subbasin, California USGS Open-File Report: 2006-1309, 8 p. http://pubs.er.usgs.gov/publication/ofr20061309

Izbicki, John A., Stamos, Christina L., Metzger, Loren F., Halford, Keith J., Kulp, Thomas R., Bennett, George L., 2008, Source, Distribution, and Management of Arsenic in Water from Wells, Eastern San Joaquin Ground-Water Subbasin, California. USGS Open-File Report: 2008-1272, 8 p. http://pubs.er.usgs.gov/publication/ofr20081272

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Other related USGS Publications

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Burow, K.R., Shelton, J.L., Hevesi, J.A., and Weissmann, G.S., 2004, Hydrogeologic characterization of the Modesto area, San Joaquin Valley California: U.S. Geological Scientific Investigations Report 2004-5232, 54 p. http://pubs.usgs.gov/sir/2004/5232/.

Faunt, Claudia C., Hanson, Randall T., Belitz, Kenneth, Rogers, Laurel, 2009, California's Central Valley Groundwater Study: A Powerful New Tool to Assess Water Resources in California's Central Valley: U.S. Geological Survey Fact Sheet 2009-3057, 4p. http://pubs.er.usgs.gov/publication/fs20093057.

Faunt, Claudia C. (editor), 2009, Groundwater Availability of the Central Valley Aquifer, California: U.S. Geological Survey Professional Paper 1766, 227 p. http://pubs.er.usgs.gov/publication/pp1766.

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Phillips, S.P., Green, C.T., Burow, K.R., Shelton, J.L., and Rewis, D.L., 2007, Simulation of multiscale ground-water flow in part of the northeastern San Joaquin Valley, California: U.S. Geological Survey Scientific Investigations Report 2007-5009, 43 p. http://pubs.er.usgs.gov/publication/sir20075009.

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